In April, 1966, the people of Los Angeles County experienced a measles epidemic. The outbreak was recognized as the ascending portion of the epidemic curve was being recorded. A mass immunization program was immediately instituted. The resultant epidemic curve was significantly skewed to the left, probably as a result of the immunization campaign.

MASS MEASLES IMMUNIZATION IN LOS ANGELES COUNTY

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Introduction

In 1963, live measles vaccine was licensed for use in the United States. By 1967, the Surgeon General had stated that eradication of measles as an epidemic disease was possible.[1] During this four-year period, over 20 million doses of measles vaccine had been distributed in the United States.[2] Intensive efforts by state and local health departments, with assistance from the National Communicable Disease Center, were responsible for this impressive job.

Several approaches can be made to control measles by immunization. Three of these are mass immunization in the face of an epidemic, mass immunization without an epidemic, and maintenance immunization. This paper concerns the experience of the County of Los Angeles, Health Department with one of the above methods of measles control—vaccinations in the face of an epidemic. The Health Department activities discussed are surveillance, campaign execution, and evaluation of campaign effectiveness. The other two methods of measles eradication will be discussed in a separate article.

Methods and Materials

Health Department Organization

The County of Los Angeles, Health Department provides health services for 6.5 million people spread over a 4,078-square-mile area. Its jurisdiction does not extend to Pasadena, Long Beach, or Vernon. Administrative headquarters collects and collates data, determines policy, and furnishes guidance to each of the 23 geographical subdivisions or health districts. The district is directed by a physician who is responsible for the success of all activities in his area.

Surveillance

Measles is a reportable disease. Confidential Morbidity Report forms are received by the department's Morbidity Section from school nurses and physicians. The data are available weekly in a Health Department publication, "Mor-

bidity and Mortality—Reportable Diseases." Disease incidence is graphed by the Division of Acute Communicable Disease Control. Charts are made current each week and are compared with epidemic curves from previous years. When indicated, clusters of cases of a communicable disease are investigated.

Vaccine

The Immunization Project Division is responsible for conducting vaccination programs against poliomyelitis, diphtheria, pertussis, tetanus, and measles. In 1965, the federal government amended the Vaccination Assistance Act of 1962 to provide grant funds for measles vaccine. Subsequently, the United States Public Health Service contracted with Los Angeles County to make measles and other vaccines available in June, 1966.

The Medical Advisory Committee to the Immunization Project had recommended live, further attenuated Schwarz strain measles vaccine because the reaction rates were slightly less following its use than with other available live measles vaccines. This vaccine cost $1.39 per injection), twice as much as the low passage, live attenuated Edmonston B strain vaccine plus gamma globulin combination (65 cents per injection) available from the Public Health Service. Since jet injector guns were not scheduled for use, the additional operational and administrative cost (75 cents per injection) for dispensing the two-injection combination matched the added vaccine cost for the Schwarz strain immunization.

The incidences of vaccine reactions to an Edmonston B vaccine* plus gamma globulin and to Schwarz vaccine† have been amply described in previous articles.[3-5] Consequently, the incidence of temperature and rash, and the per cent of seroconversions in vaccine recipients, were not studied during the campaign.

Susceptibles

The total number of children in the 23 health districts who were susceptible to measles and eligible for vaccination was calculated as follows. The total population under eleven years of age (1,494,415) was the base figure.* From this number, the figures for the following groups were substracted:

1. Children under one year (143,299)*—omitted since live vaccine not given in this age group.[6]
2. Children who have had measles (673,070)—estimated from cumulative curves on past history of measles presented by Langmuir.[7]
3. Children who had been immunized against measles (139,844)—based on vaccine distribution data from drug manufacturers for the period 1963-1965.

The final figure for the estimated number of susceptibles on January 1, 1966, was 538,202.

Vaccination Consent Form

Parental consent to administer any vaccine is required in writing by California statute. A signed consent was accepted after a parent stated his child did not have any of the contraindications for receiving measles vaccine. The questionnaire was based on the contraindications established by Public Health Service Advisory Committee on Immunization Practices.[6]

Results

Recognition of Epidemics

Measles epidemics have occurred every two or three years in Los Angeles

* Manufactured by Philips Roxane.
† Manufactured by Pitman-Moore.

* Based on January 1, 1966, Los Angeles County Regional Planning Commission population estimates prorated according to the 1960 Census age distribution.

County except after 1960, when outbreaks occurred almost annually as shown in Figure 1. No large outbreak appeared in 1965. Therefore, an epidemic was considered possible in 1966.

During late March and early April, 1966, an increase in the number of reported cases was noted. The outbreak of measles occurred as the people of Los Angeles County were recovering from a severe epidemic of Type A_2 influenza. In several communities, school absenteeism reached 30 to 40 per cent. Extensive coverage of the influenza epidemic by the various news media made the people aware of the magnitude of this public health problem.

The recognition of an incipient measles epidemic, the recent recovery from epidemic influenza, and a measles outbreak in nearby Imperial County[8] were the factors that combined to create an urgent and newsworthy situation.

Campaign Preliminaries

Vaccine. On April 12, 1966, the County of Los Angeles Health Department requested that Public Health Service funds scheduled for June be made available immediately. The request was granted.

Fifty thousand doses were needed. The Public Health Service was to pay for half of the vaccine for children under five years of age. The cost of the other half was promptly underwritten by the Los Angeles County Board of Supervisors. In addition, the supervisors agreed to provide all of the funds for immunizing children over the age of five years.

Publicity. On April 14, a news release stating that the Los Angeles County, Health Department had secured 50,000 doses of measles vaccine for emergency use was distributed to local communications media. Our own recent influenza epidemic and the measles epidemic nearby made this news.

News on a subject may create a demand for more news on that same subject. Thus an opportunity was provided for health officials to inform the public that, first, a measles epidemic threatened the children of the community; and, second, a highly effective one-shot vaccine was available without cost from the Health Department. The highly communicable nature of the disease as well as its complications were stated.

News media announced that free measles immunization clinics would be held on a county-wide basis the next day. Children through age 10, and in

Figure 1—Number of reported measles cases, Los Angeles County, by calendar year, 1941-1966

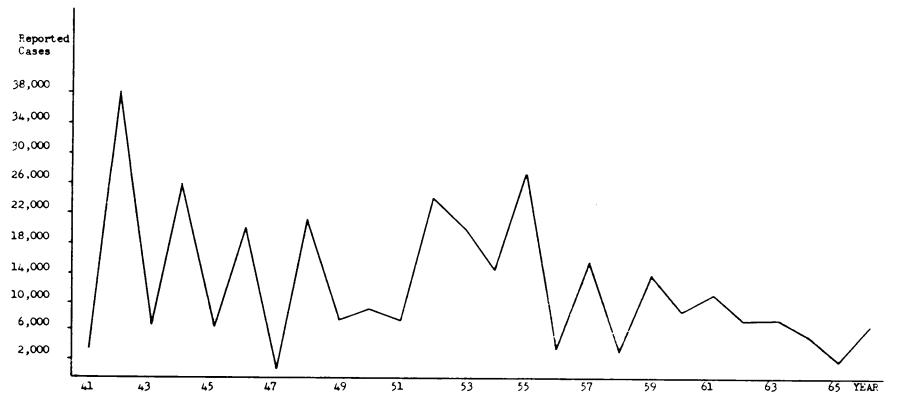
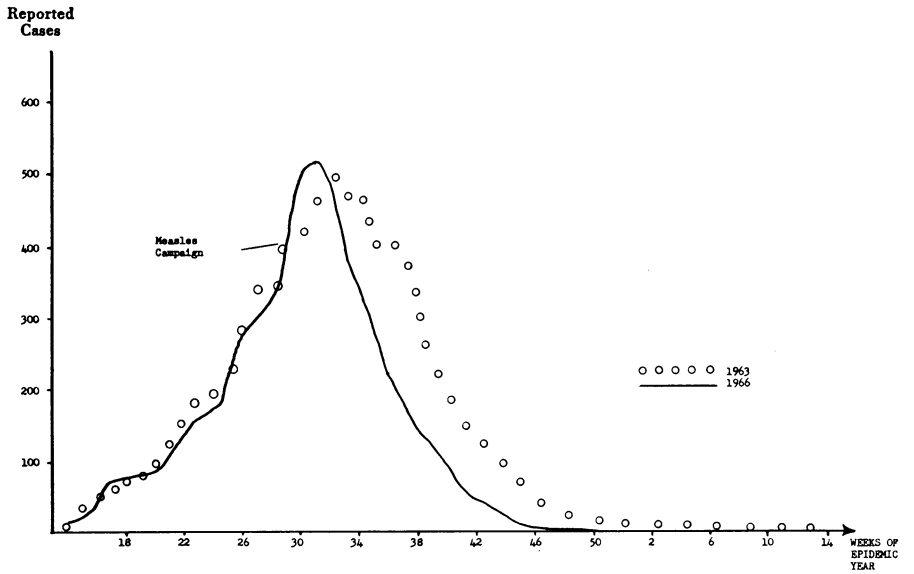


Figure 2—Number of reported measles cases by week, based on three-week moving average, Los Angeles County, for 1963 and 1966



special cases (selected chronically ill children) through age 15, would be welcome. The populace was also urged to seek immunization for children from their family physicians.

Campaign Operations

Clinics. Immunization clinics were opened April 15, 1966. There were 51 locations in operation throughout the jurisdiction of the County of Los Angeles, Health Department. Clinics also were opened in Long Beach and Pasadena.

Logistics. The large order of single-dose vaccine could not be stocked in the refrigeration space available at the 51 sites. The local vaccine vendor, however, was able to store the vaccine and distribute it to each vaccination site as needed. A central courier service was established to maintain adequate auxiliary supplies during the campaign. Ongoing health programs had to be maintained at each of the vaccination sites.

Vaccine Distribution. During the first day of the campaign, nearly 20,000 doses were given by the Health Department. It became evident that the initial order of 50,000 doses would be inadequate to meet the demand. On April 19, a second order for 50,000 doses was placed. The cost was again shared equally by the Public Health Service and the County Board of Supervisors. By April 25, ten days after the campaign opened, the demand had been met. The total number of doses given by the Health Department was 87,237.* In addition, approximately 150,000† doses were administered by private practitioners to meet the demands generated by the Health Department's program. Thus, almost one-quarter of a million doses of measles vaccine were admin-

* Includes 981 doses given by Pasadena Health Department.

† Estimates submitted by vaccine manufacturers.

istered during the epidemic. Since there were about 538,202 susceptibles, the per cent of susceptibles immunized was estimated at 44.1 per cent.

Health Department personnel gave 57,534 doses to children in the one- to five-year group and 29,522 doses in the six- to ten-year group. Only 181 doses were given to children 11 years or above. No age distribution was available for vaccine administered by private physicians. There was little, if any, association in many health districts between the number of people who took advantage of the immunization program and the need, i.e., number of susceptibles, for such a program. An analysis of the factors that relate to this behavioral or performance gap has been presented elsewhere.[9]

Campaign Effect on Epidemic

An attempt was made to demonstrate the effectiveness of the mass campaign on the course of the epidemic. The reported cases were plotted in Figure 2. In an attempt to smooth out the curve and correct the discrepancies in reporting, a three-week moving average was used. A comparison of the 1966 epidemic curve with that of 1963 shows that both curves were similar as the epidemics developed. However, after the peaks appeared, the decline in the curve was gradual in 1963 but steep in 1966. The curve for 1963 asymptotically approached the base line or abscissa at the fiftieth week. The curve for 1966, however, approached the same base line on the forty-sixth week.

The sharper decline of the epidemic curve in 1966, and its earlier approach to the base line, suggested that the epidemiologic conditions in 1966 were different from those of 1963. The measles campaign conducted in 1966, two weeks before the epidemic peak, may have been the epidemiologic factor which accounted for the difference in the two curves.

For the epidemic years 1959-1966, the per cent of cases reported after the peak of the epidemic is shown in Table 1. For 1959-1965, the simple median postpeak percentage is 53 per cent. This figure was used to calculate the expected postpeak number of cases for 1966. From Table 1, it is seen that there were 2,387 cases actually reported or 2,114 fewer than expected. Obviously 2,114 fewer measles cases is significant. One does not always need statistics to find practical significance. However, for completeness, the data were analyzed in a 2 x 2 table by chi-square. As anticipated, the difference was significant at the $p<0.01$ level.

Table 1—Determination of expected cases reported after epidemic peak

Epidemic year	Reported cases for epidemic year	Week of peak†	Percentage reported after peak
1959–1960*	8,804	30	52
1960–1961	10,933	28	59
1961–1962	7,705	29	51
1962–1963	8,115	30	55
1963–1964	5,604	32	54
1964–1965	2,046	28	51
Simple median for 1959–1965			53
1965–1966	6,378	31	37

	Epidemic Year 1965–1966	
Cases	Prepeak	Postpeak
Observed	3,991	2,387
Expected	3,991	4,501

* Epidemic Year defined, for example, as the period from the first week in October, 1959 to the first week in October, 1960.

† Peak-week arbitrarily chosen as point on epidemic curve after which curve flattened and/or declined. Points on these epidemic curves were determined from the weekly reported measles cases without bias of a moving average.

Discussion

It is difficult to prove that the measles vaccination campaign definitely altered the outcome of the 1966 measles epidemic. If we can demonstrate that (1) the vaccine administered was able to offer protection before or at the epidemic peak, (2) the number of children immunized raised the herd immunity to a level sufficient to prevent further spread of disease, and (3) the expected epidemic curve was altered, then support is given for the value of this immunization campaign toward controlling the epidemic.

The first condition concerns the time of vaccination relative to the epidemic peak. Katz[10] has shown that children are protected from natural measles on the same day that vaccine is administered. (Exceptions occur when exposure to natural measles occurs a day or more prior to vaccination.) The greater part of the vaccine given during the campaign was given before the epidemic peak. The Health Department's campaign was begun two weeks before this peak and most of the vaccine was administered in the first week of the campaign. Also, according to vaccine manufacturers, most of the vaccine given by private physicians was probably distributed before the epidemic peak. (Publicity on the epidemic was extensive prior to the peak.) Consequently, the vaccinations took effect at or before the epidemic peak. Finally, the point at which the curve peaked (based on date of report) is probably very close to the actual peak (based on date of onset) because the delay in reporting during an epidemic is minimal—about one week.

The second condition pertains to the increased herd immunity resulting from a vaccination campaign. Hedrick[11] demonstrated, in Baltimore, that measles epidemics did not develop when the level of immunity was above 55 per cent. Though the figures do not necessarily apply to all urban areas, his findings do point out that considerably less than 100 per cent of the population need become immune before an epidemic is prevented or halted. In Los Angeles County, prior to the epidemic in 1966, the measles-susceptible population under 11 years of age was 538,202 or 36 per cent of the total population under 11 years. Vaccine doses distributed by the Health Department and private physicians one to two weeks prior to the peak of the epidemic totaled 237,237. In addition (assuming a reporting efficiency of 10 per cent for the 3,979 cases reported[12]) approximately 39,790 cases of measles occurred before the epidemic peak. Thus, 277,027 children, or over 50 per cent, of the preepidemic susceptibles were immune before the epidemic peaked because they recently had been vaccinated or had had the natural disease.

Most of the children who acquired immunity between the start and the peak of the epidemic acquired it as a result of vaccination. Only 39,790 children, less than 8 per cent of the susceptibles, acquired immunity from natural measles. It is likely that the 237,237 vaccinated children, who comprised 44 per cent of susceptibles, contributed significantly to raising the level of herd immunity to a point where the epidemic could no longer sustain itself.

The third condition relates to the alteration of the epidemic curve. On the basis of previous experience with measles epidemics in Los Angeles County, we described a method for predicting the dimensions of the descending portion of the epidemic curve when given the data on the first half of that curve. The data presented in Table 1 show that the predicted number of measles cases, following the peak in 1966, was significantly greater than the actual number of cases reported. The difference from the expected number suggests that a new

variable was introduced at or prior to the epidemic peak. This variable altered the subsequent course of the epidemic. That new variable was probably the immunization campaign.

In addition to shortening the natural course of the 1966 epidemic, the impact of the campaign will be felt for many years. It has been estimated that for every 100,000 children immunized against measles, not only the same number will not suffer the clinical illness, but 15 deaths, 100 cases of encephalitis, and 25 cases of permanent mental and physical retardation will not occur.[13] Approximately 237,237 children were immunized during the immunization program. Consequently, in the coming years, about 35 deaths, 237 cases of encephalitis, and 59 cases of permanent retardation will be avoided in Los Angeles County. The cost of life-long care for one severely retarded child is estimated to be $100,000. Therefore, millions of tax dollars will be saved in the costs for hospitalization and institutionalization.

The success of the campaign was due, in part, to heightening public awareness of the dangers of natural measles. To prevent the disease, a simple, effective, and readily available vaccine was offered. The fear of complications associated with measles undoubtedly impelled parents to bring their children to private physicians or to the Health Department.

The above-reported measles campaign was our first and, at that time, in terms of numbers vaccinated, the largest attempted in this country. Detroit soon followed, vaccinating with jet injector guns over twice as many in one day.[14] We have since conducted a five-day measles campaign (June 1 through 5, 1967). Significantly, our second campaign was even more successful without the motivation of previous influenza epidemic or the threat of a measles epidemic. Constant public education of the dangers of natural measles and the availability of one-shot vaccine is surely responsible.

Campaigns such as the one described have altered the epidemiology of measles. No longer will the disease contribute as much to maintaining herd immunity. The prevention of measles epidemics will now require constant maintenance immunization programs.

Summary

A program that resulted in the immunization of over 237,000 children against measles in Los Angeles County during April, 1966, is described. The major criterion of success was a sharper decline in reported cases of measles after the mass immunization program than would have been expected from the experiences of previous years. The factors believed to have made this campaign successful, as well as its effect on the 1966 measles epidemic, are discussed. The immediate and long-term benefits that far outweigh the cost of such a program are emphasized.

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Report on Schools of Public Health

The current report on Schools of Public Health, for the year ending June 30, 1968, has now been prepared, and is available from the Book Service, APHA, 1740 Broadway, New York, N. Y. 10019, at a cost of $1. Members and Fellows of APHA may request complimentary copies. Please ask for document No. CPE-68B5.

The report presents data on organization, finances, physical premises, faculty members, curriculum, and graduates. A condensed version is due to appear in the Education Number of the Journal of the American Medical Association and in the American Journal of Public Health.